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(71) Applicant *(for all designated States except US)*: SCAN COIN AB [SE/SE]; Jagershillgatan 26, S-213 75 Malmö (SE).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)* : HOWELLS, Geoffrey [GB/GB]; 24 Pitreavie Road, Cosham, Portsmouth, Hampshire P06 2ST (GB).

(74) Agent: BARKER, BRETTELL & DUNCAN; 138 Hagley Road, Edgbaston, Birmingham B16 9PW (GB).

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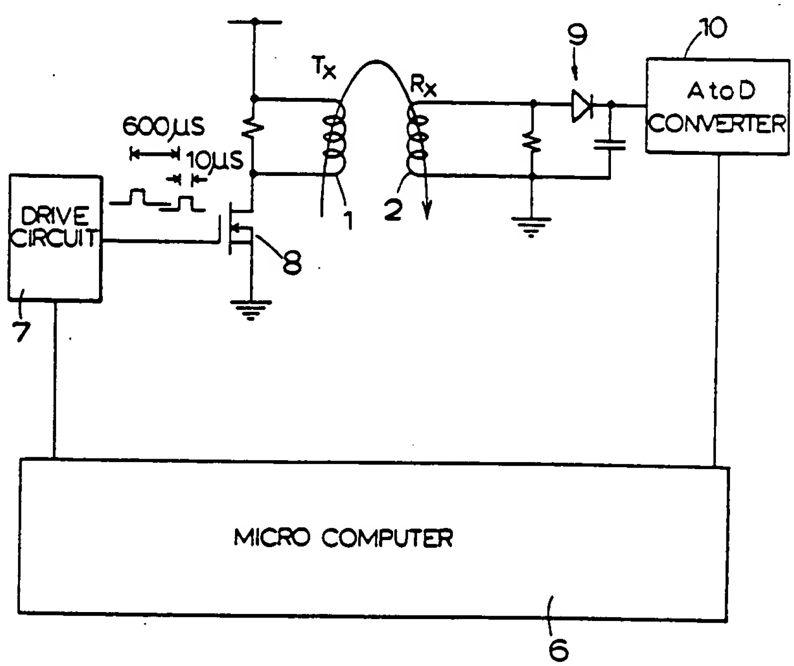
(54) Title: COIN DISCRIMINATOR

(57) Abstract

A pair of coils (1, 2) of elongate transverse cross-section face each other across a coin path, and the changes in shading of the receiver coil (2) by a coin proceeding between the coils (1, 2) is monitored by a track and store unit (6) controlled by software. The emitter coil (1) is subjected periodically to pulses having a 1 MHz frequency component to provide a sharp-edged emitter coil pulse, and the amplitude of the voltage pulse induced in the receiver coil (2) is monitored. The track and store unit (6) is programmed to locate the receiver coil pulse of minimum amplitude produced by maximum shading of the receiver coil, to determine when a coin is positioned symmetrically of the coils for a diameter measurement to be made. In order to discriminate from noise, the storage means (XDI) of the track and store software is switched by switch units (20, 21, 22) from storing the most recent maximum value of receiver coil volts (DIAM) to storing the most recent minimum value of receiver coil volts when the receiver coil signal has fallen by a predetermined threshold amount, (set in block 29), and then is switched again (at 18) following a minimum receiver coil signal (at 12) to storing again the most recent maximum value when the receiver coil signal has risen by a further threshold amount (set in block 25).



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COIN DISCRIMINATOR

This invention relates to a coin discriminator. The term "coin" is intended to include coin-like items such as bogus coins, tokens and metal blanks.

It has been proposed to measure the diameter of coins by having a line of optical detectors arranged on one side of a coin path with a light positioned on the opposite side of the coin path. The maximum number of detectors which are cut off by the coin as it passes along the coin path is then used as a measure of the coin diameter. However, coins are generally dirty and such optical arrangements can suffer from a build up of dirt which impairs their accuracy.

It has also been proposed to arrange an array of coils adjacent to the coin path and to look at the quelling of oscillations in those coils by the coin. Whilst such an arrangement is not affected by dirt, the use of several coils requires expensive circuitry. Also the coils respond to factors other than the mere dimensions of the coin, and so they do not provide a measurement of coin diameter alone. This can create another problem which is that two coins of different diameter/metal content may produce similar signatures with such a system.

According to the invention a coin discriminator comprises an emitter coil and a receiver coil positioned on opposite sides of the coin path, the coils in transverse cross-section, that is in planes which include turns of the coil, being of elongate form, the adjacent ends of the coils facing each other such that the projected area of the end face of the emitter coil is substantially superimposed on the end

face of the receiver coil, means for applying a transient voltage pulse with a large high frequency component to the emitter coil, and means for measuring the amplitude of the voltage pulse induced in the receiver coil.

The transient voltage pulse applied to the emitter coil has frequency components of at least substantially 500 kHz, and preferably at least substantially 1 MHz, such that the coin will substantially block any inductive coupling between the coils in the region where the coin masks the emitter coil.

Thus, we have, in effect, applied the masking/shadow effect of the known optical technique to the use of coils.

The emitter coil is preferably subjected to a series of discrete voltage pulses, an evaluation of the transverse dimension of the passing coin being made for each pulse.

It will be appreciated that as a coin passes between the coils the measurement of the transverse dimension of the coin will go from a minimum, when the coin first begins to intercept the coil flux lines, to a maximum when the coin is positioned symmetrically of the coils, and then to a minimum again as the coin passes from the flux lines. The measuring means is therefore arranged to detect the maximum value of the transverse dimension, (the minimum output of the receiver coil). This is preferably achieved by tracking the output of the receiver coil, but the tracking preferably needs to take account of noise which may result from various factors, and preferably it is desirable that the discriminator can deal with

touching coins. It will be appreciated that with touching coins the coil output will not rise back to a full maximum when the first coin just clears the flux lines, since the second coin will begin to intercept the flux lines.

Preferably a track and store unit is employed which can be switched by software such that either the most recent maximum or the most recent minimum of the detector coil signal is stored, the switching, from storing the most recent maximum to storing the most recent minimum, being performed when the signal has fallen by a first predetermined amount below the stored maximum value, and the switching-back, from storing the most recent minimum to storing the most recent maximum, being performed when the signal has risen again by a second predetermined amount above the stored minimum value, and the stored minimum value of the signal immediately prior to said switching-back being used as the measure of the coin diameter.

In this way the noise in the system is accommodated, since the stored minimum value is not accepted as being the true minimum value until the signal has risen again by the second predetermined amount, which amount is made sufficiently large to distinguish from noise fluctuations in the signal.

A coin discriminator in accordance with the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:-

Figure 1 is a plan view showing the passage of a coin between a pair of coils of the discriminator;

Figure 2 is a side view of one of the coils of Figure 1;

Figure 3 is a block diagram of the circuit of the discriminator;

Figure 4 is a plot of the receiver coil signal showing the effect of single coins passing between the coils;

Figure 5 is a plot similar to Figure 4 showing the effect produced by two touching coins followed by a single smaller coin;

Figure 6 is a flow diagram of the program controlling the analysis of the receiver coil signal for differentiating between single coins and touching coins.

The coin discriminator shown in the drawings comprises an emitter coil 1 and a receiver coil 2 positioned on opposite sides of a coin path 3 bounded on one side by a surface 3' across which the coins slide or roll. The coils 1 and 2 are of elongate form and are arranged so that adjacent ends of the coils face each other across the coin path 3. Coil 1 is conveniently encapsulated in the plastics material of surface 3' during moulding.

Each of the emitter and receiver coils 1 and 2 is produced by winding wire on a former 4, the cross-sectional dimensions of which determine the transverse cross-sectional dimensions of the coil. In a preferred embodiment each former 4 is 6mm wide and 22mm high, and the coils are wound to a thickness of 2mm.

The coins are arranged to pass along the coin path 3 with one edge on a datum line 5. The coils 1 and 2 are preferably positioned such that their projected area onto the coin path is spaced from the datum line 5, since the position of one edge of the coin is already known. This enables a maximum range of coin diameters to be measured with coils of specified cross-sectional dimensions. The spacing of the coils from the datum line must not, however, be so great as to permit a coin of the smallest coin type to be measured to pass undetected.

The direction of the maximum transverse dimension of each coil is arranged to be substantially at right angles to the datum line 5.

Conveniently the coins are arranged to roll along a surface which provides the datum line 5, but in a high speed machine they may be driven by a belt.

With reference to Figure 3, the pulsing of one of the coils 1,2, for example coil 1, is controlled by a microcomputer 6 through a pulse generator or drive circuit 7 and transistor switch 8, the drive circuit 7 being arranged to produce a train of 10 µs pulses with a pulse period of 600 µs. Coil 2, in this instance, acts as the receiver coil and is connected through a rectifier 9 to an A/D converter 10, the rectifier 9 providing the peak value of the induced voltage in the receiver coil 2.

The drive circuit 7 and transistor switch 8 are arranged to provide sharp-edged pulses having frequency components in the 1 MHz region.

The peak value of the voltage induced in receiver coil 2 when a coin is positioned between the coils is a measure of the length of the chord of that part of the coin which partially shades coil 2 from the influence of the transmitter coil 1.

Figure 4 shows a plot of the rectified receiver coil signal as seen by the A/D converter 10 when a single large coin passes between the coils, followed in due course by a further large coin which just enters between the coils. The receiver coil signal drops from level 11 down to a minimum signal level at point 12 when the coin is positioned symmetrically of the coils 1,2 and then rises up to the original level at point 13 as the coin leaves the projected area of the coils.

It is desired to measure the signal level at point 12, but the method of measurement needs also to take into account the situations shown in Figure 5. Figure 5 shows that two large touching coins produce a rectified receiver coil signal which has two minima at points 14 and 16 corresponding to large coins being individually positioned symmetrically of the coils 1,2, with an intervening maximum at point 15, but it should be noted that the maximum at point 15 is at a smaller signal level than the minimum at point 17 produced by a small coin in the position in which it produces maximum shading of the receiver coil 2. Figure 5 shows that a simple level detector circuit would be confused by the signals at 15 and 17, and it is accordingly desirable to be able to recognise this situation, and make diameter measurements at points 14,16 and 17 only.

The microcomputer 6 is programmed to track the rectified receiver coil signal, so as to follow the

signal and identify the minima 12,14,16,17, etc. The coil signal will also be subject to noise due to bouncing and wobbling of coins and to non-roundness of some coins. It will not, therefore, in general be sufficient to identify an apparent turning point in the curve. In accordance with a preferable feature of the invention we set a threshold amount by which the coil signal must differ from the relevant minimum or maximum before the decision is taken to accept that minimum or maximum as a valid minimum or maximum.

Thus, as indicated in Figure 4, we do not accept that point 12 is the minimum coil signal which corresponds to the coin diameter until the coil signal has risen by a predetermined threshold amount to point 18.

The software of unit 6 is arranged to store the most recent minimum value of the coil signal, that is the most recent maximum value of the measured diameter, in the region between points 11' and 18, whereupon once point 18 has been reached the value of coin diameter corresponding to point 12 is taken as the correct diameter measurement for that coin.

From point 18 onwards, as the coin progressively uncovers more of the receiver coil 2, the software is arranged to record instead the most recent maximum value of the coil signal, in order to seek out a maximum coil signal, to locate points such as 13 and 15.

Then, only when the receiver coil signal has fallen by a threshold amount (which may or may not be the same as the threshold amount associated with the location of the minimum coil signal) will the software accept that the coil signal is falling, due to another

coin rather than to noise, and switch to searching for the next minimum value of the coil voltage. Thus, in Figure 4, the switch to searching for minimum coil current rather than maximum coil current, takes place at point 19.

It will be appreciated that it is necessary to set the threshold values such that they are less than the difference in signal levels 14,15 in order that identification of both minima 14 and 16 is performed.

It is important that the tracking of the receiver coil signal and the manner of identifying the positions of the minima 14,16,17, etc., be performed in a rapid and efficient manner, and the use of thresholds as described in conjunction with switching when the thresholds are encountered from seeking a minimum to a maximum and vice versa can provide an efficient solution to this problem.

Figure 6 shows a flow diagram of the software employed to implement the method just described. The diagram is largely self-explanatory but a brief explanation will now be given.

In Figure 6 the block 20 is a flag which can be set or unset to provide the switching from seeking a minimum value of the receiver coil output to seeking a maximum of that output.

It should be noted that the flowchart of Figure 6 is written in terms of coin diameter but these are merely convenient names for the coil output. Thus the variable 'DIAM' is the current receiver coil voltage, and the variable 'MAXDI' is the currently stored value of the receiver coil voltage.

Blocks 21 and 22 provide for setting and unsetting respectively of the flag (coin=0?). When the flag has been unset in box 20 by block 22, the variable 'COIN' is set at $ff, and accordingly the answer produced by box 20 is NO, and block 23 will accordingly compare the latest diameter (chord) measurement with the currently stored minimum measurement of coil output (MAXDI). If the curve being tracked is, for example, the portion in Figure 4 approaching point 12 (as a coin approaches the maximum shading position) then the current value of DIAM will exceed the stored MAXDI to provide a YES output from block 23, and block 24 will then substitute the latest value of DIAM as the new stored MAXDI.

On the other hand, after the point 12 has been reached the result from block 23 will be NO, and the difference between MAXDI and DIAM is compared in block 25 with the threshold value, such that when eventually point 18 is reached block 26, which compares the account with zero, will on that occasion produce a YES answer whereupon block 21 will set again the flag COIN=0 in block 20, by resetting the variable 'COIN' to 0, and the subroutine of block 27 will identify the coin on the basis of the value of MAXDI. The value of MAXDI at that instant will be the measurement of coil current made at point 12.

When point 18 is reached the YES output from block 26 causes block 21 to set the flag 20, by setting the variable 'COIN' to zero, so that the next run of the program will result in a YES output from block 20. From then on the point 13 is being sought. Box 28 compares the current coil output DIAM with the currently stored value MAXDI and provides a YES output if the receiver coil output is rising, thereby causing

box 24 to store the most recent maximum value of coil output as the value MAXDI. When point 13 is reached then the value MAXDI will have been set to the coil voltage as measured at point 13.

Then, when a further coin begins to enter between the coils, the value of DIAM will begin to fall again, so that the output from box 28 will be NO, and the difference between DIAM and MAXDI (corresponding to point 13) will be compared by boxes 29 and 30 with a threshold value to seek point 19, whereupon when point 19 is reached the output of box 30 will first become YES. The YES output from box 30 will then initiate box 22 to unset the flag in box 20 by assigning the value $ff to the variable 'COIN' in box 20.

It will be appreciated that the unsetting of the flag in box 20 at point 19 will result in the most recent minimum value of coil output then being stored as MAXDI, the switching from storing the most recent maximum coil output to storing the most recent minimum coil output thereby being executed at point 19.

This program will similarly seek out the points 14,15 and 16 in the Figure 5 plot, providing of course that the difference in receiver coil voltage between points 14 and 15 is greater than thresholds provided in boxes 25 and 29.

The mechanism of setting and unsetting of a flag in box 20 in dependence upon a comparison between a most recent maximum (or minimum) coil output and a threshold amount, provides a time-efficient method of tracking the coil output curve, and constitutes a preferable feature of the present invention.

CLAIMS

1. A coin discriminator comprising an emitter coil (1) and a receiver coil (2) positioned on opposite sides of the coin path (3), pulse generating means (7,8) for applying a voltage pulse to the emitter coil (1), and monitoring means for monitoring a voltage pulse induced in the receiver coil (2), characterised in that the coils (1,2) in transverse cross-section, that is in planes which include turns of the coil, are of elongate form, the adjacent ends of the coils facing each other such that the projected area of the end face of the emitter coil is substantially superimposed on the end face of the receiver coil, in that the voltage pulse is a transient pulse with a large high frequency component, and in that the monitoring means (6,9,10) is arranged to measure the amplitude of the voltage pulse induced in the receiver coil (2).

2. A coin discriminator as claimed in claim 1 in which the large frequency component of the transient pulse is at least substantially 500 kHz.

3. A coin discriminator as claimed in claim 2 in which the large frequency component of the transient pulse is at least substantially 1 MHz.

4. A coin discriminator as claimed in any of the preceding claims in which the pulse generating means (7,8) is arranged to generate a series of voltage pulses, and the monitoring means is arranged to measure the amplitude of the induced voltage pulse corresponding to each pulse of the emitter coil, the monitoring means comprising tracking means being arranged to detect a minimum amplitude (at 12,14,16,17)

of the induced pulses, and being arranged to produce a measurement signal based upon that minimum amplitude.

5. A coin discriminator as claimed in claim 5 in which the tracking means comprises a threshold setting means (25) and a storage means (MAXDI), and the tracking means is arranged to accept a stored minimum receiver coil voltage as a true minimum only when the receiver coil voltage, for subsequent pulsing of the emitter coil, has risen by more than the threshold determined by the threshold setting means.

6. A coin discriminator as claimed in claim 5 in which the tracking means incorporates a switch means (20,21,22) arranged to control the storage means (MAXDI) such that when said threshold has been exceeded the storage means is switched to storing the most recent maximum receiver coil voltage for the next succeeding pulses applied to the emitter coil, and the switch means is arranged subsequently to switch the storage means (MAXDI) back to storing the most recent minimum value of the receiver coil voltage when that voltage executes a fall which exceeds a further threshold value set by a further threshold setting means (29).

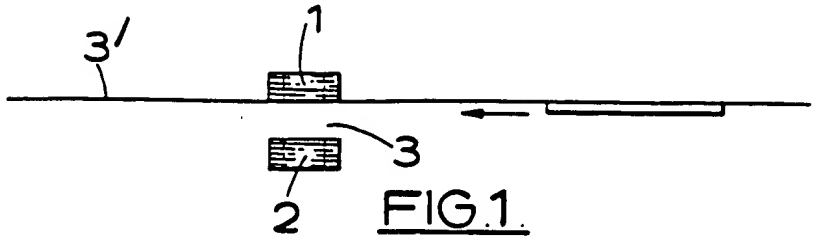

FIG.1.

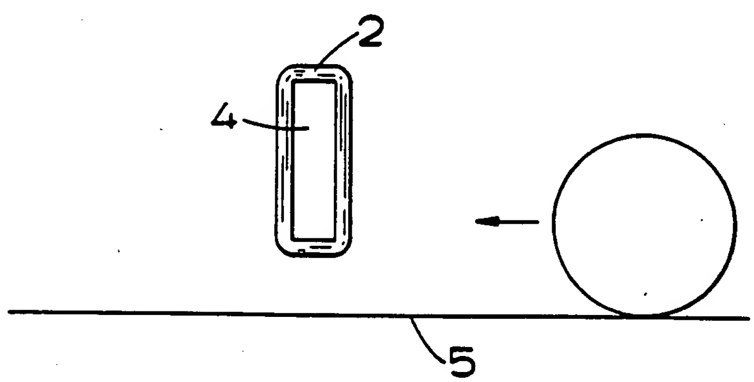

FIG.2.

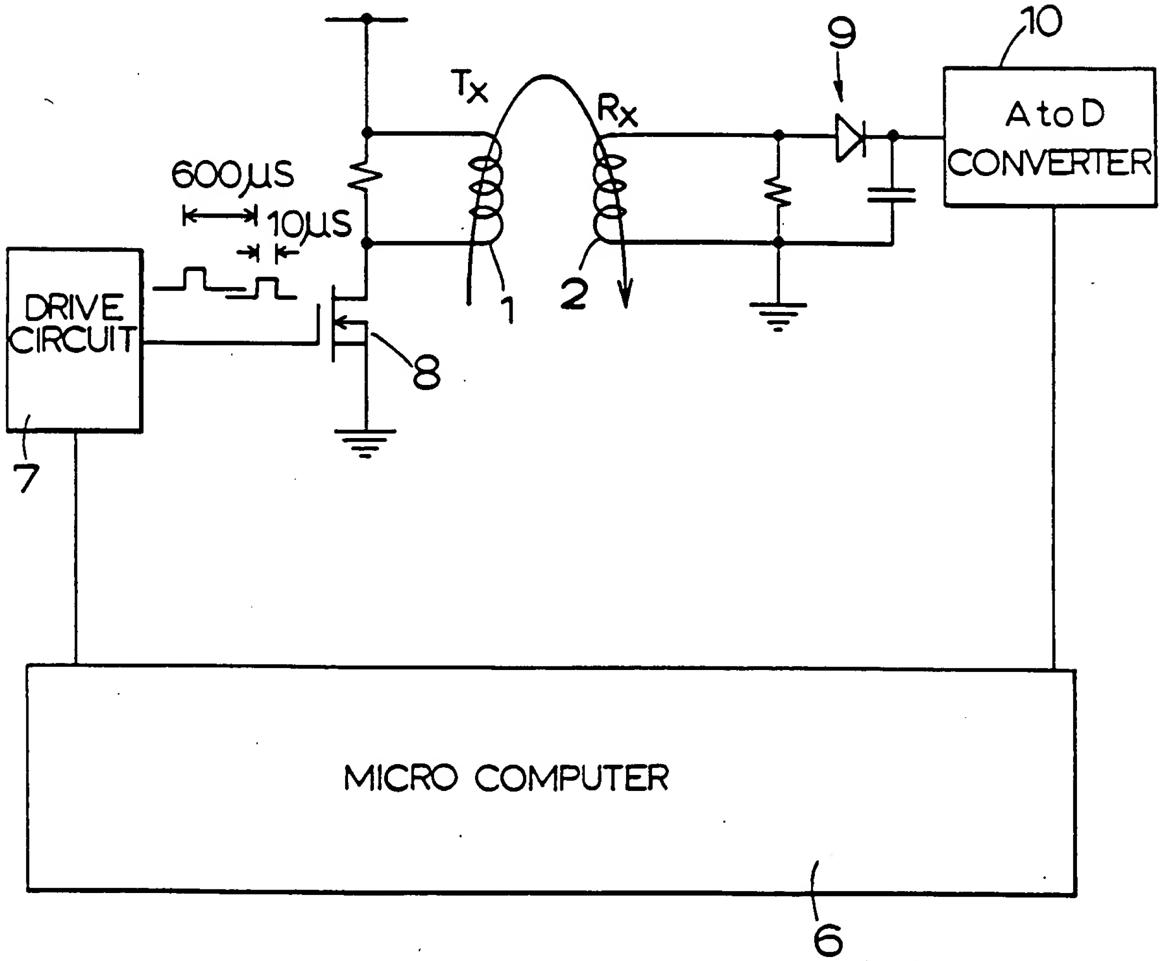
600µs
10µs
DRIVE CIRCUIT
7
8
Tx
Rx
1
2
9
10
A to D CONVERTER
MICRO COMPUTER
6

FIG. 3.

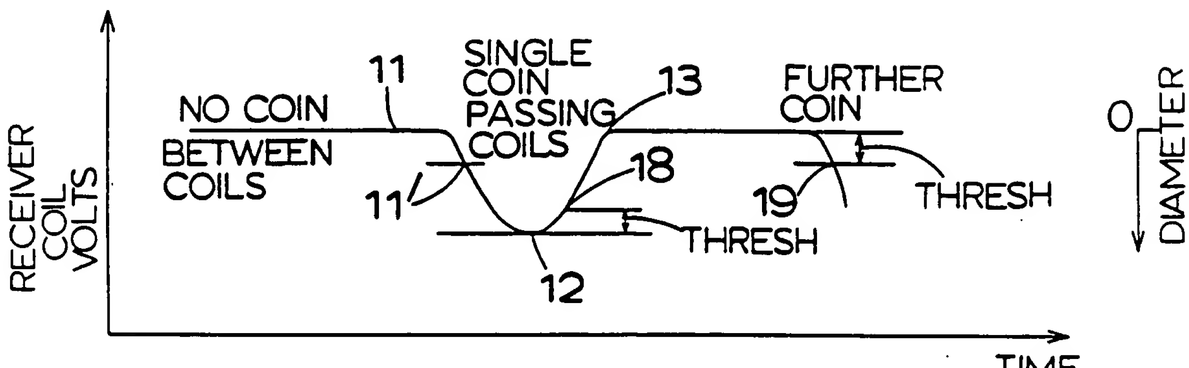
RECEIVER COIL VOLTS
NO COIN BETWEEN COILS
11
11'
SINGLE COIN PASSING COILS
13
18
12
THRESH
FURTHER COIN
19
THRESH
0
DIAMETER
TIME

FIG.4.

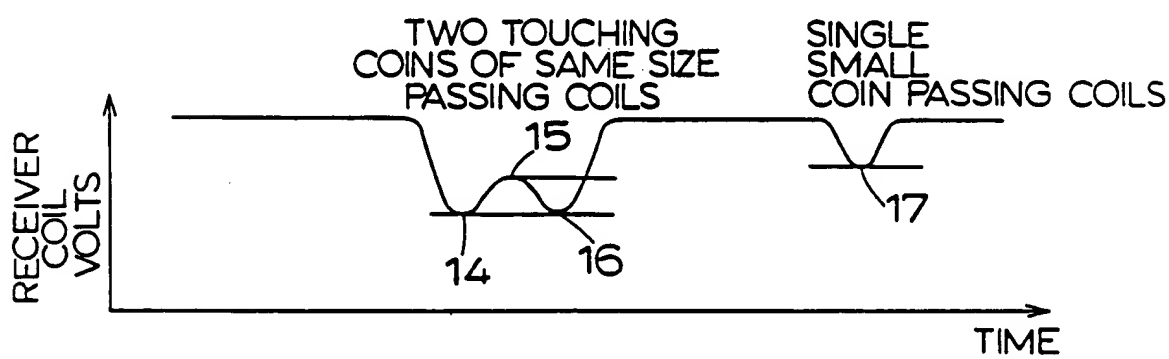
RECEIVER COIL VOLTS
TWO TOUCHING COINS OF SAME SIZE PASSING COILS
15
14
16
SINGLE SMALL COIN PASSING COILS
17
TIME

FIG.5.

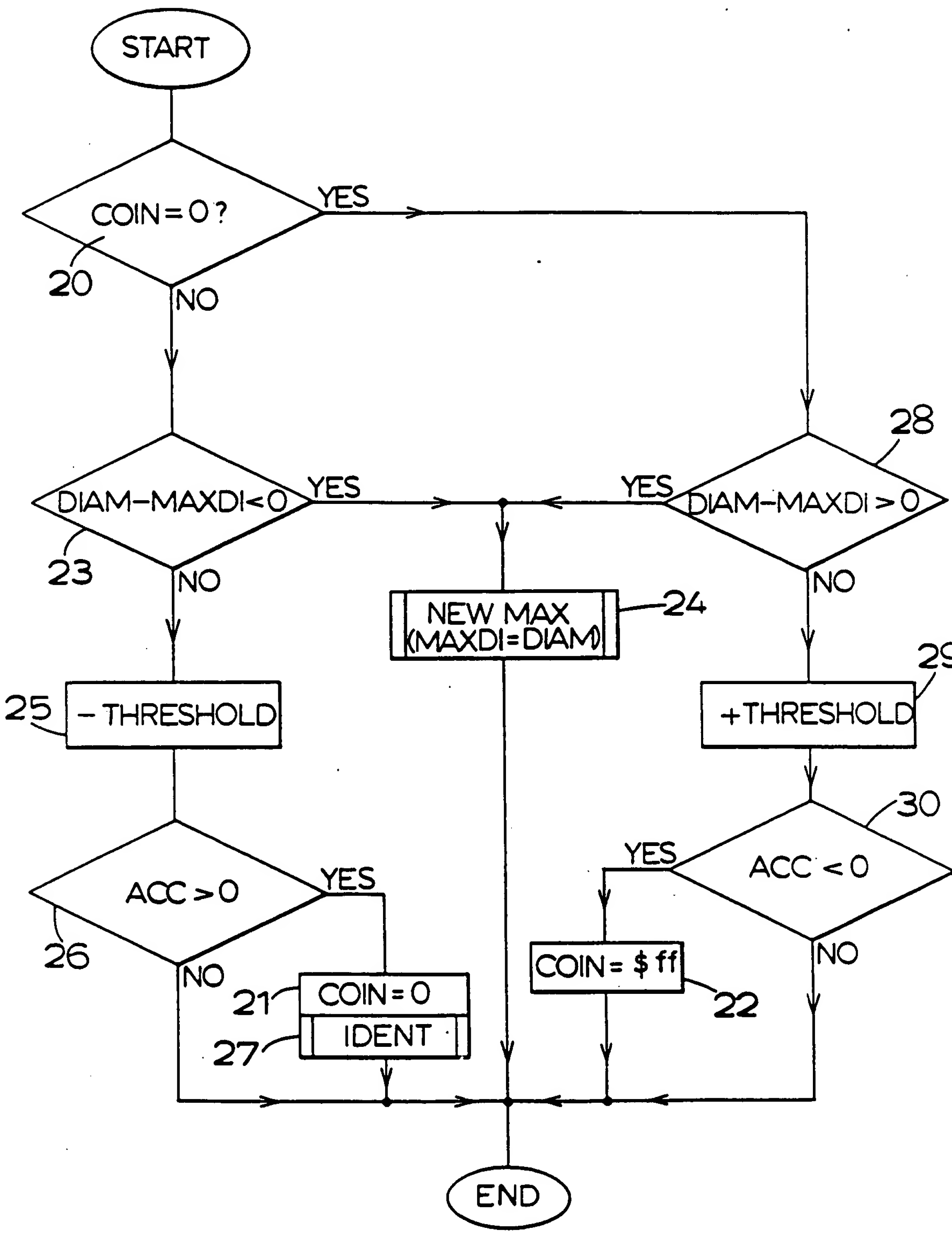
START
COIN=0?
20
YES
NO
DIAM-MAXDI<0
23
YES
NO
28
YES
DIAM-MAXDI>0
NO
NEW MAX
(MAXDI=DIAM)
24
25
-THRESHOLD
29
+THRESHOLD
30
ACC>0
26
YES
NO
ACC<0
YES
NO
COIN=0
21
IDENT
27
COIN=$ff
22
END

FIG.6

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 88/00592

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: G 07 D 5/08, G 07 F 3/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	G 07 D, G 07 F

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	EP, A, 0119000 (CHAPMAN) 19 September 1984, see page 6, lines 5-10; page 7, lines 11-29; page 13, line 27 - page 14, line 3; figure 4 --	1,4,5
Y	US, A, 4353453 (PARTIN) 12 October 1982, see column 3, lines 13-38; column 4, lines 52-62; column 5, line 30 - column 6, line 24; figures 2,7,9,10 --	1,4,5
A	US, A, 4660705 (KAI) 28 April 1987, see column 2, line 34 - column 3, line 3 --	1
A	US, A, 4286704 (WOOD) 1 September 1981, see column 2, lines 12-20 --	1
A	US, A, 4436196 (CRISP) 13 March 1984, see abstract --------	1

* Special categories of cited documents: [10]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
22nd September 1988	17 NOV 1988
International Searching Authority	**Signature of Authorized Officer**
European Patent Office	P.C.G. VAN DER PUTTEN

Form PCT/ISA/210 (second sheet) (January 1985)

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP,A 0119000	19/09/84	AUD 24242/84	16/08/84
		GB 2135095	22/08/84
		GB 2135492	30/08/84
		JP 59189490	27/10/84
		US 4717006	05/01/88
US,A 4353453	12/10/82	None	
US,A 4660705	28/04/87	EP 0164110	11/12/85
		JP 60262292	25/12/85
US,A 4286704	01/09/81	GB 2049252	17/12/80
		DE 3015814	06/11/80
		JP 55146591	14/11/80
		AUD 57750/80	30/10/80
		AU 537066	07/06/84
US,A 4436196	13/03/84	EP 0043189	06/01/82
		GB 2078420	06/01/82
		AUD 71683/81	24/12/81
		AU 549910	20/02/86

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